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(54) LIQUID DROP GENERATOR

(71) We, XEROX CORPORATION, a corporation organised under the laws of the State of New York, United States of America, of Rochester, New York 14644, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

This invention relates to liquid drop generators such as ink jet assemblies.

In an ink jet assembly wherein ink droplets are expressed from a chamber by selectively increasing the pressure therein, the means for increasing the pressure in the chamber may be piezoelectric or magnetostrictive actuators. The actuators are normally premanently secured to the ink jet assembly requiring new actuators each time an assembly must be replaced. The actuators comprise a substantial proportion of the cost of the assembly. Therefore, if the actuators are reusable so they may be used with replacement assemblies, a substantial savings can be achieved. A proposal for reusable actuators for ink jet assemblies is given in U.S. Patent 3,864,685.

The present invention is concerned with providing improved liquid drop generators having reusable actuators. The structure and operation of such generators differs from that described in U.S. Patent 3,864,685.

According to the invention there is provided a liquid drop generator comprising a liquid jet instrument for holding a liquid supply and a drive unit for expressing liquid drops from said instrument, said liquid jet instrument being releasably secured to said drive unit and comprising a nozzle assembly, a chamber housing operatively associated with the nozzle assembly, means enabling the supply of liquid to said housing, said housing having a plurality of separate chambers, each chamber having an opening therethrough, and elastic diaphragm means sealing the chamber openings, the nozzle assembly having a plurality of outlet orifices from which liquid drops are expressed, each outlet orifice being in operative communication with at least one of the chambers, and said drive unit comprising a carrier member provided with a plurality of means for applying pressure pulses to said diaphragm means, said carrier member maintaining each pressure pulse applying means in operative association with the diaphragm means at a respective one of the chambers.

There is also provided according to the invention a liquid drop generator comprising a liquid jet instrument for holding a liquid supply and a drive unit for expressing liquid drops from said instrument, said liquid jet instrument being releasably secured to said drive unit and comprising a nozzle assembly, a chamber housing operatively associated with the nozzle assembly, means enabling the supply of liquid to said housing, said housing having a chamber which has an opening therethrough, and an elastic diaphragm means sealing the opening of the chamber, the nozzle assembly having at least one outlet orifice in operative communication with the chamber and from which liquid drops are expressed, and the drive unit comprising a carrier member provided with means for applying pressure pulses to said diaphragm means, said carrier member maintaining the pressure pulse applying means in operative association with the diaphragm means at the chamber.

Preferred features of the invention will be described with reference to the accompanying drawings wherein:-

Figure 1 is a perspective view of a multiple ink jet printing system which includes an ink jet assembly according to the invention;

Figure 2 is a section view of a portion of a piezoelectric driver bar employed in the

apparatus shown in Figure 1;

Figure 3 is a view taken along section line 3-3 of Figure 1;

Figure 4 is a view taken along section line 4-4 of Figure 1;

Figure 5 is a top view of a coincidence ink jet unit according to the invention;

Figure 6 is a bottom view of the coincident ink jet unit of Figure 5;

Figure 7 is a view taken along section line 7-7 of Figure 5;

Figure 8 is a front view of the unit of Figures 5-7 illustrating piezoelectric drivers releasably attached thereto;

Figure 9 is a perspective view of a multiple ink jet printing system having magnetic driver means;

Figure 10 is a view taken along section line 22-22 of Figure 9; and

Figure 11 is a view taken along section line 33-33 of Figure 9.

Referring to Figures 1-4, a multiple ink jet assembly is arranged opposite a rotating recording medium 12 for depositing ink droplets thereon. The assembly comprises a driver unit 14 releasably secured to an ink jet instrument unit 10. The instrument 10 comprises an elongated plastic or ceramic chamber unit 16, a plastic or ceramic multiple nozzle unit 18 attached to the front of the chamber unit 16 and a plastic or ceramic manifold reservoir unit 19 attached to the rear of the chamber unit. The chamber unit has a plurality of rectangularly shaped chambers 20 separated by side walls 21 projecting upwards from a bottom wall 22. An elastic thin diaphragm 24 spans the chamber body and is sealed to the upper edge of each wall 22 to form an outer wall of the chamber body. The elastic diaphragm 24 comprises an elastic material, such as stainless steel, glass or nickel.

The driver unit 14 comprises an electrically conductive elastic metallic web 26, a plurality of longitudinally spaced piezoelectric ceramic members 28 bonded to the web 26, a plurality of electrodes 30 bonded to a respective one of the piezoelectric members 28 and a ceramic or plastic carrier bar 32. The piezoelectric members 28 and the electrodes 30 are circular in the preferred mode but may be square or rectangular. The piezoelectric member 28 is polarized during the manufacture thereof to contract in a radial direction. A plurality of electrical leads 34 are each connected to a respective electrode 30 and an electrical lead 36 is connected to the web 26. The leads 34 and 36 are connected to electrical drivers (not shown) so that the electrode 30 for each piezoelectric member may be separately addressed. The carrier bar 32 includes a plurality of cylindrical cavities 38, each of which has a ridge 40 on the closed end wall 41 thereof. The ridge 40 circumscribes a circle on the wall 41. The surface of the ridge is located a distance "d" from the face 42 of the carrier bar 32, which is less than the combined thickness "t" of the piezoelectric member 28 and electrode 30. The metal web 26 is bonded by any well-known adhesive to the portions of the face 42 of the carrier bar, which are located between the cavities 38 in such a manner to press the electrode 30 into engagement with the ridge 40. Due to the difference in the combined thickness "t" of the piezoelectric member 28 and electrode 30 and the distance "d" between the face 42 and the ridge 40, the web 26 will be slightly deformed when the web 26 is bonded to the carrier bar 32.

A flange 44 is provided on each longitudinal end of the carrier bar 14, and a complementary flange 46 is provided on each longitudinal end of the chamber housing. The carrier bar 14 and the chamber housing 16 are assembled together and attached to longitudinally spaced support flanges 48 (only one shown), located adjacent each longitudinal end thereof, by a bolt 50 and nut 52 assembly. The degree of deformation of the web 26, due to the protrusion of the piezoelectric member 28 beyond the face 42, is such that the diaphragm 24 will be slightly stressed when carrier bar 14 and the chamber housing 16 are assembled together to assure that the diaphragm wall 24 conforms to the shape of the deformed web 26 in a normal position. Upon applying a voltage across the piezoelectric member 28, the piezoelectric member 28 will deform causing the diaphragm 24 to similarly deform to decrease the volume of the chamber 20 to express an ink droplet therefrom. Upon termination of the voltage application, the diaphragm 24 returns to its normal position due to the elasticity thereof to restore the liquid volume of the chamber 20.

The multiple nozzle unit 18 is of thin plastic wall construction and comprises a plurality of ink jet droplet orifices 54 separated by a wall therebetween. The nozzle unit has a plurality of spaced ledges 55 which are sealed to the front portion of the diaphragm 24. The nozzle unit is also sealed to the walls 21 and the bottom wall 22 with one orifice being communicated with one chamber.

The manifold ink reservoir unit 19 is also of thin plastic wall construction and has a plurality of spaced ledges 57 which are sealed to the back edge of the diaphragm 24. The reservoir unit is also sealed to the walls 21 and the bottom wall 22 and is communicated to the individual chambers 20 through a plurality of orifices 56. The reservoir orifice 56 is more restrictive to flow from the chamber than the droplet orifice 54 whereupon pressure developed in the chamber 20, due to deformation of the diaphragm 24, will express a droplet from the nozzle orifice 54 rather than force fluid back to the reservoir through orifice 56. Upon relaxation of

the diaphragm, fluid from the reservoir will replace the ink express d from chamber 20. A primary reservoir 58 supplies the manifold reservoir through a conduit 60 and may be kept at a pressure of about 6 inches of liquid.

In operation, a voltage is selectively applied to the piezoelectric member 28 of various selected chambers to cause deformation of the diaphragm 24 thereat to express ink droplets from the nozzle orifice 54 associated therewith. Ink droplets will be deposited on the recording medium, in accordance with a desired image, as the recording medium 12 rotates past the ink jet assembly unit 2.

When it is desired to replace the instrument 10, the assembly 2 is removed from the support flange 48, the instrument 10 replaced and the assembly of the new instrument and old driver unit secured to the support flange 48. The piezoelectric members are usable with a number of ink jet assemblies saving the cost of providing new piezoelectric members for each new assembly.

Referring to Figures 5-7, there is illustrated a coincidence ink jet assembly to which the principle of this invention may also apply. A coincidence jet assembly is the subject matter of U.S. Patent No. 4,104,645 and comprises two liquid ink pressure passages and a droplet outlet orifice. Each of the pressure passages is communicated to a respective pressure chamber. An ink droplet is expressed from the outlet orifice only when the liquid in both the pressure passages has a simultaneous increase in pressure.

Referring to Figure 7, there is illustrated a section view of an ink jet instrument housing 100, which includes a pair of circular pressure chambers 101 and 102. Main fluid pressure passages 104 and 105 lead from the chambers 101, 102, respectively, to pressure inlet passages 106, 107, which lead to a liquid ink supply passage 108 where the three passages intersect. The liquid ink supply passage 108 branches off from two parallel main supply passages 110 and 112, which, in turn, are joined at one end inside the housing by a cross-passage 114 and at the other end by an external C-shaped tubular fitting 116. A flexible bag ink reservoir 120 is communicated to the tubular fitting 116 by a conduit 122. Also, at the intersection is an outlet orifice 124 through which ink droplets 126 are expressed onto a copy medium.

The chambers 101 and 102 are each sealed by a respective elastic diaphragm 128, which is secured to the housing 100 by a suitable adhesive. The chambers and passages are entirely filled with liquid. When the diaphragm 128 for either chamber 101 or 102 is deformed, a pressure increase will occur in that particular chamber causing displacement of ink in a respective one of passages 106 and 107.

The relationship between the above described chambers, passages and the droplet outlet orifice is now described for an understanding of a coincidence ink jet principle. The passages 106 and 107 are at such an angle relative to the orifice 124, the impedance to liquid flow in passage 108 relative to the impedance to liquid flow in orifice 124, and the magnitude and duration of a pressure increase exerted on the liquid in the pressure chambers 101, 102 are designed that the ink stream expressed from only one passage at a time will entirely miss orifice 124 and displace the ink in the ink supply passage 108, while the ink within orifice 124 will not be disturbed to the extent of expressing a droplet therethrough. The orifice 124 is so located relative to the intersection of the passages 106, 107 and the magnitude and duration of the pressure increase exerted on the liquid in the pressure chambers 101, 102 are so designed that the summation vector of the fluid momentum vectors in passages 106 and 107 will lie on the axis of the orifice 124. Thus, only when the diaphragm 128 for both pressure chambers 101, 102 is simultaneously deformed, thereby applying a simultaneous pressure increase in the liquid in each of passages 106, 107, will an ink droplet 126 be expressed from orifice 124.

The aforedescribed coincidence ink jet principle has specific utilization in a matrix actuation system where a large number of jets or a dense linear jet array is employed since substantially fewer pressure chambers than the number of jets utilized are required. Theoretically, since two independent pressure chambers are required to effect expression of an ink droplet through a jet, the number of pressure chambers required in a matrix actuation system is twice the square root of the number of jets. For example, theoretically, only 120 pressure chambers are needed for 3600 jets. Each jet orifice is communicated to two pressure chambers. However, as the number of jets increases in a system, the number of jets communicated to one pressure chamber will be hydraulically limited and, therefore, more pressure chambers may be required. For instance, the practical number of pressure chambers for a 3600-jet instrument may range between 120 and 400. In this instance, a housing would be provided with a plurality of pressure chambers, each serving a number of ink jets. The embodiment of Figures 5-7 illustrates a nine-jet, six-pressure chamber ink jet instrument. Each orifice 130, 132, 134, 136, 138, 140, 142 and 144 has pressure inlet passages 106, 107 and a fluid supply passage 108 communicated to it in exactly the same manner as described for orifice 124. The pressure chambers 146, 148, 150 and 152 are the same as chambers 101

and 102 and each is sealed by separate diaphragms 128. For clarity, Figure 5 illustrates fluid passages between only the chambers 101, 146 and 148 and their respective ink jet orifices; and Figure 6 illustrates the fluid passages between only the chambers 102, 150 and 152 and their respective ink jet orifices. Also, some of the passages are cross-hatched and filled with dots for clarity in showing separate passages. Chamber 101 is communicated to the jets 124, 134 and 140 by main passage 104; chamber 146 is communicated to the jets 130, 136 and 142 by passage 154; and chamber 148 is communicated to jets 132, 138 and 142 by passage 156. Chamber 102 is communicated to jets 124, 130 and 132 by passage 105; chamber 150 is communicated to jets 134, 136 and 138 by passage 158; and chamber 152 is communicated to jets 140, 142 and 144 by passage 160. The following table shows which jets express droplets therefrom when particular chambers are pressurized:

Chambers *Simultaneously Pressurized*	Droplet *Expressed From Jet*
102, 101	124
102, 146	130
102, 148	132
150, 101	134
150, 146	136
150, 148	138
152, 101	140
152, 146	142
152, 148	144

Referring to Figures 7 and 8, a pair of driver units 162, 164 is removably secured to a stationary support 186. Each driver unit is constructed in the same manner as driver unit 14 with a piezoelectric member 168 for each chamber disposed in a respective cavity 170 of a carrier bar 172. An elastic metallic web 171 is bonded to each piezoelectric member and the carrier bar 172 and engages each diaphragm 128 to exert a slight stress thereon. Electrically insulated lead wires 174 are connected to a respective thin electrically conductive metallic plate 176 bonded to the piezoelectric member 168. An electrically insulated lead 178 is connected to the web 171. A plurality of electronic drivers are electrically connected to a respective one of lead wires 174 and 178 to selectively apply a voltage across a selected piezoelectric member 168. When an ink droplet is desired through a particular orifice, a voltage is applied across the piezoelectric members corresponding to the particular two chambers which need to be pressurized to express a droplet through such orifice. When a voltage is applied to a piezoelectric member, deformation of the piezoelectric member will cause the diaphragm 128 to deform resulting in decreasing the volume of its respective pressure chamber and increasing the pressure therein. The liquid droplet instrument is sandwiched between the driver units 162 and 164, which have flanges 180 at the longitudinal ends thereof. A bolt 182 extends through the flanges and a support flange 184 to secure the ink jet assembly to a stationary support structure 186. When it is desired to replace the ink jet instrument with a new one, the drivers 162 and 164 are removed from the support flange 184, housing 100 removed and replaced with a new one and the drivers resecured to the support flange 184. Thus, the piezoelectric members are usable with a number of ink jet instruments saving the cost of providing new piezoelectric members for each new instrument.

The diaphragm 24 for the embodiment of Figures 1-4 spans the entire chamber housing. There may be substituted therefor a plurality of diaphragms, one for each chamber. Similarly, a continuous diaphragm web may span the housing 100 to seal chambers 101, 146 and 148 and another continuous diaphragm web may seal the chambers 102, 150 and 152 rather than employing separate diaphragms 128 for each chamber of the embodiment of Figures 5-8.

Referring to Figures 9 - 11, an alternative embodiment of this invention, ink jet instrument unit 200 is arranged opposite a rotating recording medium 400 for depositing ink droplets

thereon. A magnetic driver bar 100 is releasably secured to the ink jet instrument unit 200. The instrument 200 comprises an elongated plastic or ceramic chamber unit 120, a plastic or ceramic multiple nozzle unit 140 attached to the front of the chamber unit 120 and a plastic or ceramic manifold reservour unit 150 attached to the rear of the chamber unit. The chamber unit has a plurality of chambers 160 separated by side walls 180 projecting upwards from a bottom wall 190. An elastic diaphragm 220 spans the chamber body and is sealed to the upper edge of each wall 180 to form an outer wall of the chamber body. The diaphragm 220 comprises two laminated layers 222, 224 of different materials which have significantly different strain characteristics in the presence of a magnetic field, resulting in buckling of the diaphragm when such a field is applied thereto. An example of two such materials is nickel for layer 222 and an iron cobalt nickel alloy, such as Supermendur, for layer 224. The change in length, relative to its original length, is substantially greater for Supermendur than for nickel at any given magnetizing force. When buckling or deformation of the diaphragm occurs, the Supermendur layer will form the longest surface (convex surface) of the ribbon in the buckling direction and the nickel layer will form the shortest surface (concave surface) of the ribbon in the buckling direction.

The magnetic driver 100 is secured to a stationary support member 226 by bolts 228 which extend through longitudinally spaced flanges 229. The driver is made of a material which is highly permeable to magnetic fields but of low electrical conductivity to minimize eddy current losses. Such materials may comprise a class of materials known as ferrites. The driver 100 includes a plurality of legs 230, adjacent pairs of which embrace a respective chamber 160 to form horseshoe magnets. A plurality of electrically insulated conductors 232 are wrapped in a coil around a respective one of the sections 234 of the driver, which are located between each leg 230. The coiled conductors are connected to electrical drivers (not shown) so that each coil may be separately addressed. When current is passed through the coiled conductors 232, the magnetic field lines will be generated along the axis of the coil or in the longitudinal direction. The magentic field lines will be isolated within a respective chamber are so only the corresponding diaphragm section is stressed when current is passed through a particular coil. The stress on the diaphragm 200 exerted by the magnetic field will be in a direction parallel to the direction of the magnetic field lines; thus in a longitudinal direction. Referring to Figure 10, the stress exerted on the diaphragm will cause an unequal strain on layers 222 and 224 thereby effecting buckling of the diaphragm in the longitudinal direction with the convex or longest surface 224 thereof facing the interior of the chamber 160, resulting in decreasing the volume of the chamber to express an ink droplet therefrom.

The multiple nozzle unit 140 of thin plastic wall construction and comprises a plurality of ink jet droplet orifices 238 separated by a wall therebetween. The nozzle unit has a plurality of spaced ledges 239 which are sealed to the front edge of the diaphragm 220. The nozzle unit is also sealed to the walls 180 and the bottom wall 190 with one orifice being communicated with one chamber.

The manifold ink reservoir unit 150 is also of thin plastic wall construction and has a plurality of spaced ledges 241 sealed to the back edge of the diaphragm 220. The reservoir unit 150 is also sealed to the walls 180 and the bottom wall 190 and is communicated to the individual chambers 160 through a plurality of orifices 240. The reservoir orifice 240 is more restrictive to flow from the chamber than the droplet orifice 238 whereupon pressure developed in the chamber 160, due to deformation of the diaphragm 220, will express a droplet from the nozzle orifice 238 rather than force fluid back to the reservoir through orifice 240. Upon relaxation of the diaphragm fluid from the reservoir will replace the ink expressed from chamber 160. A primary reservoir 242 supplies the manifold reservoir through conduit 244 and may be kept at a pressure of about 6 inches of liquid.

The liquid droplet instrument 200 is releasably connected to the magnetic unit by magnetic attraction between the horseshoe magnets and the diaphragm 220. However, additional appropriate connecting means can also be provided for releasably securing the instrument to the magnetic driver unit. Thus, the instrument 200 may be removed from the driver 100 and replaced allowing the same driver to be used with a number of instruments.

In operation, current is selectively passed through the coiled conductors 232 of various selected chambers to cause deformation of the diaphragm 220 thereof to express ink droplets from the nozzle orifice 238 associated therewith to deposit ink droplets on the recording medium, in accordance with a desired image, as the recording medium 400 rotates therepast.

While the described embodiments of the invention have a multiple orifice nozzle assembly associated with a plurality of chambers, it is possible to apply the invention ot a liquid drop generator including a nozzle assembly having a single outlet orifice, which orifice is in operative communication with a single chamber having an opening sealed by the pulse operable diaphragm means.

WHAT WE CLAIM IS:-

1. A liquid drop generator comprising a liquid jet instrument for holding a liquid supply

and a drive unit for expressing liquid drops from said instrument, said liquid jet instrument being releasably secured to said drive unit and comprising a nozzle assembly, a chamber housing operatively associated with the nozzle assembly, means enabling the supply of liquid to said housing, said housing having a plurality of separate chambers, each chamber having an opening therethrough, and elastic diaphragm means sealing the chamber openings, the nozzle assembly having a plurality of outlet orifices from which liquid drops are expressed, each outlet orifice being in operative communication with at least one of the chambers, and said drive unit comprising a carrier member provided with a plurality of means for applying pressure pulses to said diaphragm means, said carrier member maintaining each pressure pulse applying means in operative association with the diaphragm means at a respective one of the chambers.

2. A liquid drop generator according to claim 1 wherein the diaphragm means comprises a plurality of separate diaphragms, one being provided to seal each chamber opening.

3. A liquid drop generator according to claim 1 wherein the diaphragm means comprises an elastic web spanning two or more of said chamber openings, said elastic web constituting a common diaphragm for said two or more chamber openings.

4. A liquid drop generator according to any of claims 1 to 3 wherein the pressure pulse applying means includes piezoelectric members.

5. A liquid drop generator according to claim 4 wherein the piezoelectric members are supported on said carrier member by electrically conductive elastic web means bonded to said carrier member, said electrically conductive elastic web means being disposed face to face against said elastic diaphragm.

6. A liquid drop generator according to any of claims 1 to 3 wherein said diaphragm means is arranged to deform and reduce the volume of a chamber associated therewith upon the application of a magnetic field thereto and said pressure pulse applying means includes means for producing a said magnetic field.

7. A liquid drop generator according to claim 6 wherein said diaphragm means comprises laminated layers having significantly different strain characteristics in the presence of said magnetic field.

8. A liquid drop generator according to claim 6 or 7 wherein said carrier member comprises a plurality of horseshoe electro-magnets, one such magnet being associated with each chamber, and means for individually actuating any of said magnets as desired.

9. A liquid drop generator according to any of claims 1 to 8 wherein there is only one chamber in operative communication with each outlet orifice and liquid is expressed from said orifice when the volume of said chamber is reduced by application of a said pressure pulse to the diaphragm of said chamber.

10. A liquid drop generator according to any of claims 1 to 8 wherein there are two chambers in operative communication with each outlet orifice and liquid is expressed from said orifice only when the volume of each of said two chambers is simultaneously reduced by simultaneous application of pressure pulses to the diaphragms of said two chambers.

11. A liquid drop generator according to claim 10 wherein a group of said chambers opens onto one surface of said housing and another group of said chambers opens onto another surface of said housing, with separate portions of said drive units being located adjacent each said surface.

12. A liquid drop generator according to claim 11 wherein said surfaces are opposed.

13. A liquid drop generator according to any of claims 1 to 12 wherein said carrier member includes means for enabling said generator to be fixedly supported on a supporting structure.

14. A liquid drop generator comprising a liquid jet instrument for holding a liquid supply and a drive unit for expressing liquid drops from said instrument, said liquid jet instrument being releasably secured to said drive unit and comprising a nozzle assembly, a chamber housing operatively associated with the nozzle assembly, means enabling the supply of liquid to said housing, said housing having a chamber which has an opening therethrough, and an elastic diaphragm means sealing the opening of the chamber, the nozzle assembly having at least one outlet orifice in operative communication with the chamber and from which liquid drops are expressed, and the drive unit comprising a carrier member provided with means for applying pressure pulses to said diaphragm means, said carrier member maintaining the pressure pulse applying means in operative association with the diaphragm means at the chamber.

15. A liquid drop generator substantially as herein described with reference to Figures 1 to 4, 5 to 8, or 9 to 11 of the accompanying drawings.

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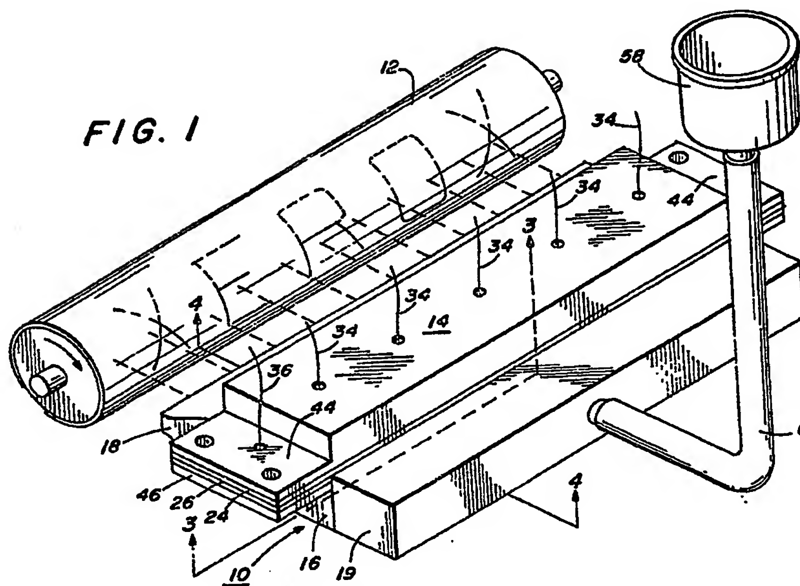
Sheet 1

FIG. 1



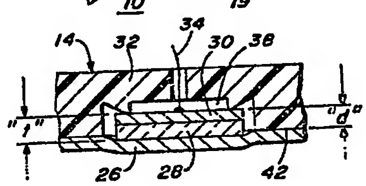


FIG. 2

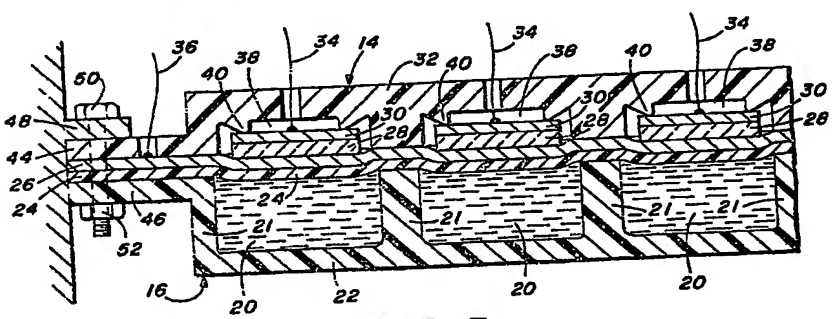


FIG. 3

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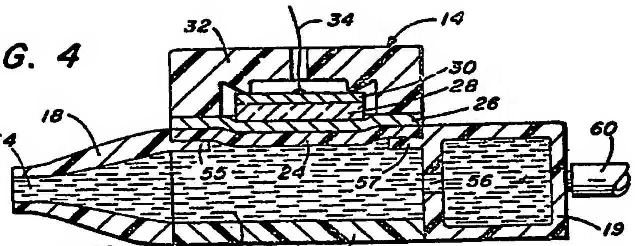
Sheet 2

FIG. 4



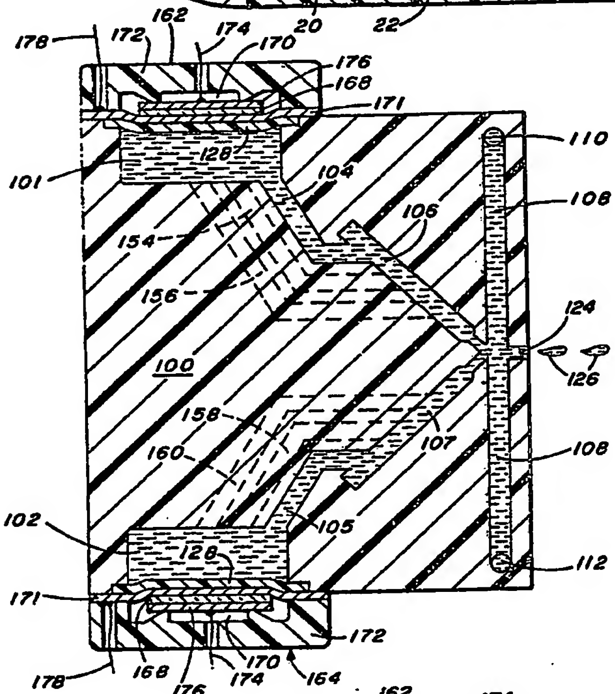


FIG. 7

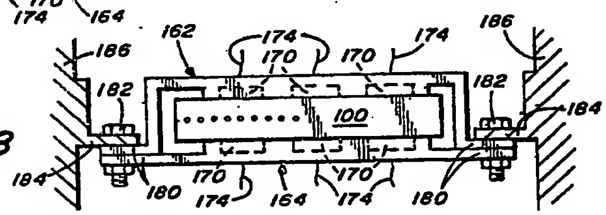


FIG. 8

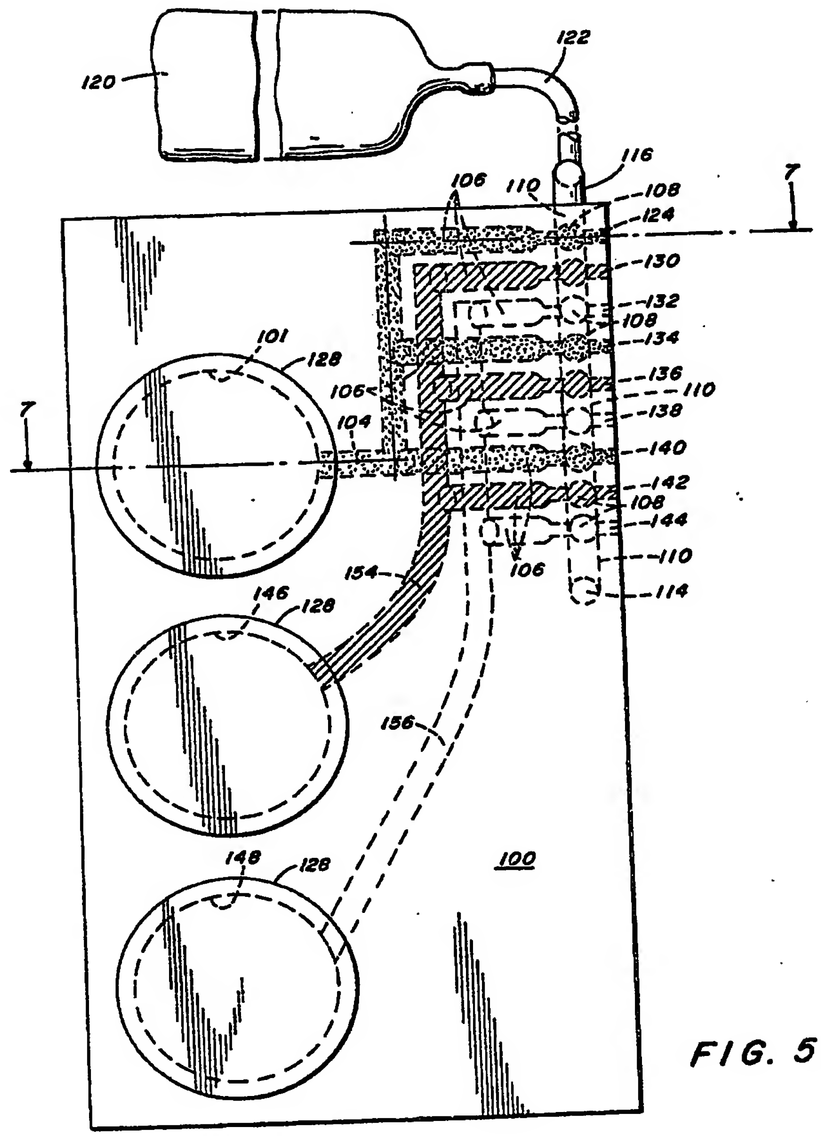

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FIG. 5

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Sheet 4

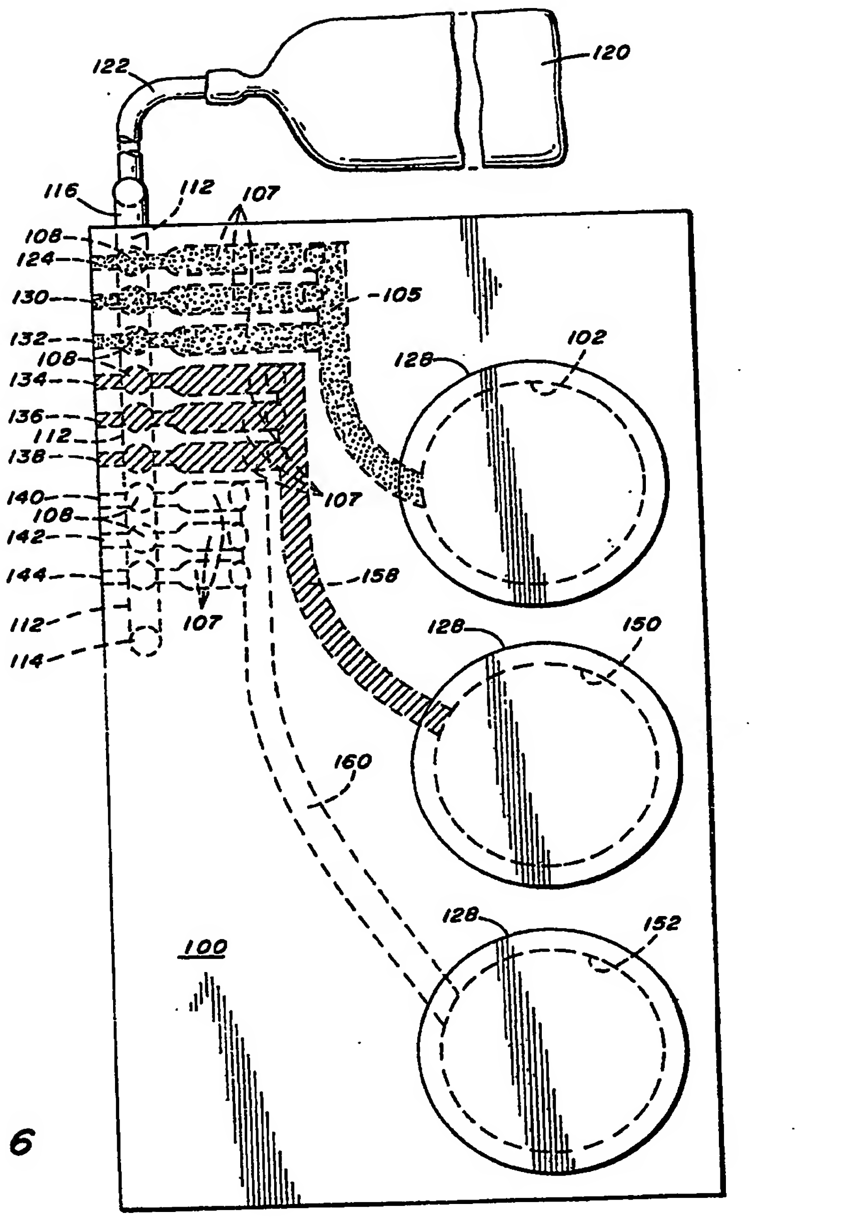

FIG. 6

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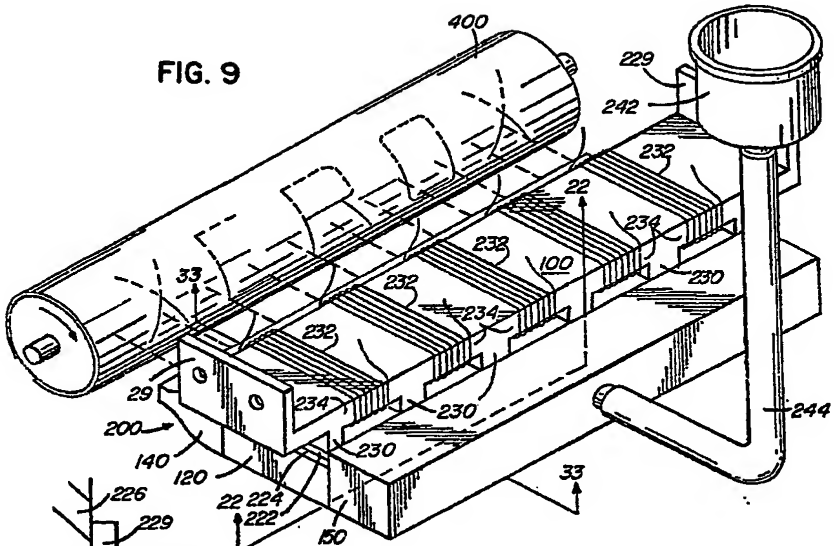
Sheet 5

FIG. 9



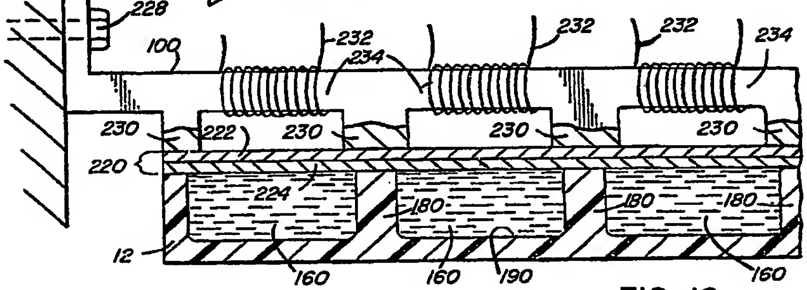


FIG. 10

FIG. 11